Heating Magnetic Structures in the Solar Corona

Jason G. Porter/ES82
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One of the main problems of solar physics is describing the processes that heat the Sun's extended outer atmosphere, the solar corona. During the past year, a group of solar astrophysicists from MSFC and the University of Tokyo have been using data from the MSFC vector magnetograph, together with data from the soft x-ray telescope on the Japanese Yohkoh satellite, to determine the causes of some of the variations in the heating rate between different magnetic structures in the corona. These structures take the form of loops arching up into the corona, following the magnetic lines of force between areas of opposite polarity in the photosphere (the "footpoints" of the loops). The team has found an apparent example of the energy transfer from active low-lying loops into higher, more-extended loops. These observations suggest that the coronal heating energy from the compact low-loop site is injected into the neighboring loops as waves that dissipate in the body of the high loops, rather than in the form of coronal plasma or energetic particles.

In figure 19, a Yohkoh soft x-ray telescope image is superposed on black and white contours, enclosing areas of positive and negative flux in the MSFC magnetogram. The main features in the x-ray image are: (area 1) a bright region along the northern portion of the main neutral line between positive and negative

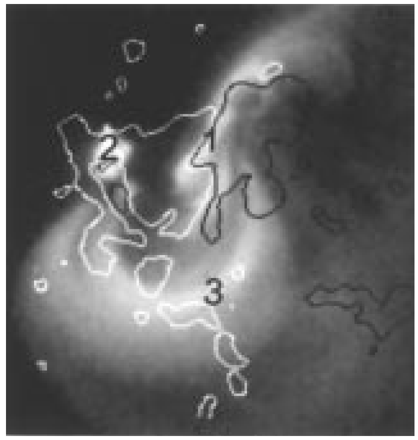

FIGURE 19.—Soft x-ray image superposed on contours of magnetic field strength.

areas; (area 2) a compact bright region spanning a secondary neutral line north of an island of included positive polarity within the main negative polarity region; and (area 3) several high, bright loops having one end rooted in the main patch of positive polarity, with the other lying in negative polarity near the included positive island. This image is the earliest obtained of the x-ray brightening in area 2, associated with the beginning of an Hα subflare. However, the high loops in area 3 showed enhanced emission for more than an hour prior to the start of the subflare, and continued to do so for more than an hour after it ended, with no evidence of the enhancement evolving to higher loops during this time. This argues against heating of the high loops by a flare-like internal release of energy triggered by the subflare near their footpoints.

Figure 20 shows more detail from the magnetogram of the region. Comparison with figure 19 shows that the west end of the enhanced loops lies in a broad region of moderately high positive field strength, on the order of 500 Gauss, lying between the two main positive flux concentrations. The east end is rooted in negative flux near the island of positive flux. One might ask why should these particular loops, out of all the magnetic loops filling space in and about the active region, show enhanced x-ray emission? A plausible answer is that some special activity near their feet drives enhanced coronal heating in only these loops. The obvious candidate for the seat of this localized anomalous activity is the east-end island of reversed polarity.

A sequence of x-ray images (taken after the one shown in fig. 19) shows smaller brightenings in area 2 (microflares). The high loops of area 3 also fluctuate in brightness throughout this time. Throughout the sequence, there is a clear emission gap separating the subflaring/microflaring low loops rooted in the included polarity island and the associated high

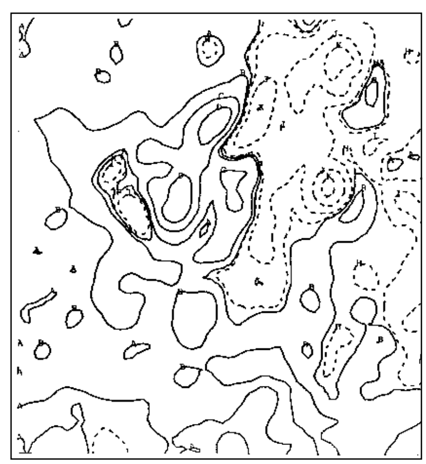

FIGURE 20.—Detailed magnetogram.

loops rooted nearby. This gap shows there is no direct transfer or generation of energetic particles and hot coronal plasma at an interface between the low loops and the feet of the high loops (the mechanism suggested for most reported observations of energy transfer between structures during flares). Instead, the microflares may generate waves that propagate into and dissipate along the nearby high loops. The fact that these microflares have little signature themselves in soft x-ray telescope observations can be accounted for by another recent analysis showing that the emission from small microflares is cooler than that from large microflares and subflares,[1] i.e., the heating leading to the continuously enhanced emission from the high loops may be maintained via a series of small events whose energy first goes preferentially into motion, generating waves, rather than directly heating plasma to coronal temperatures.

[1]Porter, J.G.; Fontenla, J.M.; and Simnett, G.M. 1995. *Astrophysical Journal*, 438, 472.

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